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DERWENT-WEEK: 200206

TITLE: Permanent mould for metal, plastic or glass casting -
has highly thermally conductive material coated on inner
surface with low conductivity and wear resistant material
joined by metal diffusion process

INVENTOR: BETZ, G

PATENT-ASSIGNEE: BETZ G[BETZI]

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BASIC-ABSTRACT:

At least part (15) of a permanent mould is of a material of high thermal conductivity and this is coated on its inner shaping surface with a layer (16) of a second material of lower thermal conductivity, together with high thermal shock and abrasion resistance. The ratio of thermal conductivities is between 5:1 and 15:1 and the thickness of the coating material is adjusted as a function of the required local heat flow density. Also claimed is a method of mfr. of a permanent mould in which a permanent metallic joint is formed between the mould material and the coating material by a high temp.- high pressure

metal diffusion process at a temp. of 850-1200 deg.C and
pressure of 250-2500
bar. Pref. the first material is Cu or a Cu alloy contg. 8% max.
alloying
addns. and the second material is a hot work steel.

USE - Casting metal, plastic, or glass

ADVANTAGE - Heat flow can be adjusted as required.

ABSTRACTED-PUB-NO: EP 711615B

EQUIVALENT-ABSTRACTS:

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CHOSEN-DRAWING: Dwg.1/3

TITLE-TERMS: PERMANENT MOULD METAL PLASTIC GLASS CAST HIGH THERMAL CONDUCTING MATERIAL COATING INNER SURFACE LOW CONDUCTING WEAR RESISTANCE MATERIAL JOIN METAL DIFFUSION PROCESS

DERWENT-CLASS: A32 L01 M22 P53

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MOULDS AND METHOD OF MAKING THE SAME

Technical Field and Background of the Invention

This invention concerns improvements in or relation to moulds, and also a method of making moulds.

In a range of net-shape manufacturing processes, it is of critical importance to transfer heat as rapidly as possible to and from the surfaces of a mould, die or core which is in contact with the material which is being formed into a net shape product. Such processes include plastic injection moulding, pressure diecasting, blow moulding and glass forming. In such processes, hot material in a soft or liquid state is injected into a mould forming the shape of the product being manufactured. The mould can be two-part or multi-part, with or without cores.

The material is cooled to a temperature at which it can be handled without damaging the component produced. The mould is then opened and the component ejected. The mould is then closed ready for the next injection cycle. To minimise the cycle time in order to maximise productivity, it is important to cool the injected material as rapidly as possible. Cooling must be spatially uniform to minimise distortion of the component after ejection, as otherwise uneven thermally induced stresses could occur in the component.

When used in this specification the term "mould" is to be understood as denoting a mould, die, or similar tool, which is usable in one or more of the above or similar processes.

Summary of the Invention

According to the present invention there is provided a mould, the mould comprising a first part made of a first material, the first part forming the mould surface; a second part made of a second material of a relatively high thermal conductivity, which thermal conductivity is significantly greater than that of the first material; and a third part of a third material, the third part being interposed between the first and second parts, the third part being in the form of a relatively thin layer, the third material being of a type to form

metallic bonds respectively with the first and second materials.

The third material preferably has a thermal conductivity which is not significantly less than the thermal conductivity of the first material, and desirably the thermal conductivity of the third material is greater.

The first material preferably comprises steel, preferably a tool, die or mould steel, and may be of the through-hardenable, prehardened, case hardening, corrosion resistant or maraging type. Typical examples would be H13 and AISI 420.

The second material may comprise copper, or a copper alloy, and desirably a copper alloy having a thermal conductivity greater than $60Wm^{-1}deg^{-1}C$ and preferably greater than $100Wm^{-1}deg^{-1}C$.

The third material may comprise nickel or a nickel alloy.

The second part may be in the form of one or more inserts locatable in one or more recesses in the first part.

The first part preferably provides a required minimum thickness of material for all of the mould surface, and said thickness may be 0.5mm.

The third part may be in the form of a coating on the first or second part or both. The coating is preferably between 2 and 200µm thick, and where the coating is formed by electroplating it is preferably 5 to 50µm thick and desirably substantially 25µm thick.

Holes may be provided extending through at least the first part to permit ejector pins to extend therethrough for rejection of items from the mould, or for core pins or slides.

Passages may be provided extending through the first and/or second

parts to permit cooling fluids and/or heating elements to extend therethrough. Desirably each passage only passes through components made of the first or second material and not both. An insert of the first material may be provided in the second part to receive a passage from the first part, or vice versa.

The mould may comprise a number of cooperable parts, with each part being according to the invention.

The first part may be made in two sections, a first section which defines the mould surface, and a second outer section. The second section may be made of a different material or grade of material to the first section.

Insert members may be provided in the second part. The insert members are preferably of a material of lower thermal expansion than the second material, and may be of the first material. The first part may be in the form of a generally constant thickness layer on the second member, and the layer may be 1 to 8mm thick.

The part of the first part which faces the second part and/or the part of the second part which faces the first part preferably have a relatively large surface area. Formations may be provided on said facing part or parts to increase the surface area, and said formations may comprise any of serrations, grooves or fins. Corresponding interengaging formations are preferably provided on each of the first and second parts.

The invention further comprises a method of making a mould, the mould being according to any of the preceding fourteen paragraphs.

A composite blank of the first, second and third materials is preferably produced, and then at least the first material machined to produce a mould, which mould is desirably substantially polished.

The composite blank may be formed by locating the first, second and

third materials together and subjecting to hot isostatic pressing to form metallic bonds respectively between the first and third, and second and third materials.

The pressing may take place in a sealed container, and preferably at a temperature of 400 to 1350°C, and desirably at a pressure of 400 to 3000 bar. The sealed container is preferably substantially evacuated of fluids prior to pressing.

Alternatively, the composite blank may be formed by locating the first, second and third materials together and subjecting to uniaxial pressing to form metallic bonds respectively between the first and third, and second and third materials.

The third part is preferably applied on to the first or second part by electroplating. Alternatively, the third part may be provided as a foil or applied by electroless plating.

The mould may be heat treated before and/or after machining.

The second part may be formed by machining.

Where the second part is in the form of one or more inserts locatable in one or more cavities in the first part, the second part may be formed by filling the or each cavity in the first part with the second material in powder form, which powder forms the second part during uniaxial or hot isostatic pressing.

Alternatively, the second part may be cast in the or each cavity in the first part.

When a method according to either of the above paragraphs is used, the walls of the or each cavity are preferably initially coated with a layer of the third material, which coating is preferably greater than 25μm thick.

Where the first part is in the form of a substantially constant thickness layer, the underside (non-moulding surface) of the first part may be machined from a block of first material. The second part is desirably subsequently located against the underside of the first part. The second part may be cast either directly on to the first material with the third part already located thereon, or may be cast separately.

The second material may be formed by locating the second material in powder form on the first part with the third part already located thereon, with the powder forming the second part during hot isostatic or uniaxial pressing.

Once the second part has been formed and bonded to the underside of the mould surface of the first part, the first part is preferably formed by machining.

The first part may be formed by hot isostatic or uniaxial pressing of powdered first material. The powder may be located against a former, which former could be produced by rapid prototyping. The first part may be formed as a layer between two formers.

The invention still further provides a method of forming a mould, the method comprising forming at least the part of the mould which provides the mould surface by hot isostatic pressing a powder located against one or more formers.

The invention yet further provides a method of forming a mould, the method comprising forming at least the part of the mould which provides the mould surface by uniaxial pressing a powder located against one or more formers.

The former may be made of steel, graphite or ceramic. These materials may be machined from solid; sintered from powder; or cast.

The invention also provides a mould, the mould comprising a first part of a first erosion resistant material, the first part forming the mould surface; a base part; a third part of a third material interposed between the first and base parts, the third part being in the form of a relatively thin layer, the third material being of a type to form metallic bonds, respectively with the first material and the material of the base part; channels being provided in the upper surface of the base part which surface engages against the third part, the channels being such as to enable cooling fluids and/or heating elements to be contained therein.

The third part is preferably between 5 and 50µm thick, and desirably substantially 25µm thick.

The channels preferably have a width and depth of between 2 and 10mm.

The channels are preferably lined with pipes. The pipes may be made of nickel. Alternatively the pipes may be made of copper or of stainless steel, and desirably with a nickel coating on the outside thereof.

The first part and/or the base part may be made of a tool or mould steel, and the base part may be made of a lower grade material. The third material is preferably nickel or a nickel alloy.

A second part may be provided on the surface of the base part, and the second part preferably comprises a material of greater thermal conductivity than the first material. A layer of third material may be provided between the second part and the base part. The second part may be in the form of a substantially uniform thickness layer, which may be between 0.5 and 15mm thick.

The second material may comprise copper or a copper alloy.

The first part is preferably in the form of a substantially uniform

thickness layer, which is desirably between 1 and 8mm.

The invention still further provides a method of forming a mould according to any of the preceding eight paragraphs.

The first part may be formed by machining a block of first material to a depth corresponding to the final thickness of the first part below the eventual mould surface; the base part is formed to correspond to the shape of the machined surface of the block of first material, a continuous slot is machined in the surface of the base part, the third part is provided between the first and base parts which are joined by hot isostatic pressing; the first part is subsequently machined to provide the mould surface.

The slots may be lined with pipes, and desirably pipes which during the hot isostatic pressing expand to fill the slots. Alternatively the pipes may be filled with a sacrificial powder such as graphite which is subsequently removed.

Where a second part is provided between the first and base parts, the second part is preferably located therebetween prior to pressing. The second part may be formed by casting, machining, electroplating on to the first or third part, or by filling the space between the first and base parts with powdered second material which bonds together during hot isostatic or uniaxial pressing.

Brief Description of the Drawings

Embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:-

Fig. 1 is a diagrammatic cross-sectional view of a mould according to the invention; and

Figs. 2 to 12 are similar cross-sectional side views of different moulds according to the invention during formation.

Description of the Preferred Embodiment and Best Mode

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Fig. 1 shows a mould 10 which comprises a block 12 of tool steel. The

upper surface 14 of the block 12 has been machined to provide a required contour to define a mould cavity with other such moulds. Three recesses 16,18,20 are provided in the undersurface of the block 12 each extending to the same short spacing from the top thereof. Respective correspondingly shaped inserts 22,24,26 are provided slidingly located respectively in the recesses 16,18,20. The inserts 22,24,26 are electroplated with nickel to provide a coating thereof of substantially 25µm.

The block 12 is formed from a tool steel H13. Alternatives would be a maraging tool steel, P20, AISI 420 or other alternatives. The inserts 22,24,26 are formed of C101 copper alloy but could be formed from copper, or copper chromium or copper zirconium or copper chromium/zirconium alloys, ODS copper alloys, or other high conductivity copper alloys including nickel containing and beryllium containing alloys.

Also provided in the block 12 are two through holes 28 to receive ejector pins, a hole 30 for separate cores, and a looped cooling channel 32. To avoid difficulties of machining dissimilar materials and avoid galvanic corrosion effects, it is desirable that cooling passages do not pass through the different materials of the block 12 and inserts 22,24,26. In view of this a lower part 34 as shown in the drawings of the insert 26 is formed of similar steel to the block 12, and the channel 32 extends therethrough.

The mould 40 of Fig. 2 is similar to the mould 10 except that the insert 26 is not formed in two parts, and the method and formation will therefore be described together. As indicated above an initial block 12 is taken and machined to provide the recesses 16,18,20. The nickel coated inserts 22,24,26 are located in the recesses and the mould 10 is placed in a steel can 42 and hot isostatically pressed. This causes the nickel to form metal bonds with the inserts 22,24,26 and more particularly with the surrounding surfaces of the block 12 to provide a good bond between the inserts 22,24,26 and the block. Following pressing the surface 14 is machined and polished.

In use, the mould 10 is found to have advantageous performance in that the inserts 22,24,26 of high thermal conductivity allow for quick cooling of moulded items. The nickel interlayer permits different expansion between the copper alloy and the steel, and absorbs stresses therebetween during formation and also use. The nickel layer also provides for good heat transfer therebetween. The moulds 10,40 can be made to be appropriate for any of the above described techniques.

Fig. 3 shows a mould 44 which is generally similar to the moulds 10,40 except that a lower part 46 of the block 12 is made of a lower grade steel and thus cost less.

The mould 48 of Fig. 4 is again similar except that a main core 50 of the insert 26 is made of steel which may be tool steel or low carbon or low alloy steel. This reduces thermal expansion mismatch and also cost, whilst providing better mechanical strength than a wholly copper alloy insert.

Rather than preforming the inserts, copper alloy powder could be located in the recesses 16,18,20, which (using suitable canning arrangements) can form the inserts 22,24,26 during hot isostatic pressing. Alternatively, the copper alloy could be cast into the recesses 16,18,20 to form the inserts 22,24,26. In either of these instances the recesses 16,18,20 require initial lining with a layer of nickel, which is preferably more than 25µm thick.

Rather than provide copper alloy inserts a copper alloy could be provided beneath the whole of the moulding surface 14. In Fig. 5 there is shown a mould 52 with a solid block of copper alloy 54 beneath a uniform thickness layer 56 of steel. The mould 52 is formed by correspondingly shaping the steel block 12 and alloy block 54 such that their connection is spaced approximately 5mm below the required moulding surface 14. A layer of nickel is again provided in-between and the two blocks 12,54 are bonded by hot isostatic pressing. The block 12 is subsequently machined and then polished to provide the moulding surface 14. The mould 58 of Fig. 6 is similar except that a lower part 60 of the

block 54 is formed of a low cost steel to provide the above outlined advantages. The block 54 could in fact be formed by casting or from powder as outlined above.

Fig. 7 shows a mould 62 in which cooling channels in the form of slots 64 are provided extending in an upper surface of a low alloy steel block 66. The slots 64 are lined with pipes 68 which are formed of nickel or nickel coated copper which during hot isostatic pressing expand to substantially fill the slots 64. A substantially uniform layer 70 of tool steel is provided on top of the block 66 to provide a moulding surface 14. The mould 62 is formed by shaping the block 66 and a block 72 of tool steel which subsequently provides the layer 70, and bonding these together with an intermediate nickel layer by hot isostatic pressing. The majority of the block 72 is then machined away to leave the layer 70. This provides for cooling channels immediately below the moulding surface which considerably increase the rate of heat removal. The channels conform to the shape of the mould cavity and are a uniform depth from the moulding surface, thereby providing consistent cooling. The pipes 68 used are flexible prior to pressing and thus usable with a wide range of shapes of mould. If pipes of a type which may collapse during pressing are used, these can be filled with a sacrificial powder such as graphite powder which can be subsequently oxidised in air.

Fig. 8 shows a similar mould 74 except that a copper alloy uniform thickness layer 76 is provided beneath the mould surface layer 70 and above the block 66. The layer 76 can be formed by any of the above described methods and will be metallurgically bonded to the block 66 and layer 70 by an intermediate nickel layer during hot isostatic pressing.

Rather than machining the steel part of the moulds, this can be formed by hot isostatic pressing of steel powder. Fig. 9 illustrates such an arrangement with a metal former 78 coated with a diffusion barrier to form a mould 80 from powdered steel which is located thereagainst and sandwiched by a solid base member 82 which may be formed of copper alloy, steel or otherwise, with a

nickel layer being provided on the top of the base member 82.

Fig. 10 shows a similar arrangement but where a thinner substantially uniform thickness layer 84 of tool steel is formed. In this instance the lower base member 86 has an upper contoured surface to correspond to the underside of the former 78. A filling hole 88 extends through the base member 86 to enable powdered material to be located between the former 78 and member 86.

Fig. 11 shows combinations of the above arrangements with a mould 90 with a base member 92 having slots 94 with pipes 96 therein to provide fluid cooling, and with a layer 98 of tool steel thereon to form a moulding surface 14. The mould 100 of Fig. 12 is similar to the mould 90 except that beneath the layer 98 is provided a layer 102 of copper alloy, and the slots 94 extend through the layer 102. The layer 102 is approximately 5mm thick and may be electro-deposited on to the steel brace member 104. Alternatively, the layer 102 may be formed by machining or casting. Nickel intermediate layers are again provided to ensure good bonding during the hot isostatic pressing.

There are thus described a number of moulds and methods for making moulds which provide considerable advantages over prior arrangements. Various modifications may be made without departing from the scope of the invention. For example it can be advantageous for there to be a higher surface area between the tool steel or similar and the copper alloy or similar. This can be provided by providing cooperating formations such as grooves, fins, serrations or other formations to provide good heat transfer. Other formations or features could be provided than those described above.

Whilst hot isostatic pressing has been described in many of the above examples, in many instances it would also be possible to use uniaxial pressing. Heating elements could be provided in additional channels. It is to be realised that any combination of the above features can be made as conditions dictate. Where a former is used, rather than steel or another metal, graphite or castable ceramic could be used. In the latter case this is particularly advantageous in

that the former can readily be formed, and materials can easily be removed therefrom.

Whilst endeavouring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the Applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.